

Correlations between motor and cognitive skills in young basketball players: A bivariate regression analysis

F Policastro^{1*}, A Accardo², R Marcovich³, G Pelamatti¹ and S Zoia¹

¹Department of Life Science, University of Trieste, Italy

²Department of Architecture and Engineering, University of Trieste, Italy

³Department of Medical Science, University of Trieste, Italy

Abstract

The present literature highlights the importance of the cognitive aspects in the motor development of the sporty, Typically Developing children. The cognitive aspects permit to investigate how overcoming our self-limits, by increasing the expectations. The cognitive development is a ground-variable of the motor development, and enriches it.

In this study we refer to young basketball players aged between 7 and 11 years old. We propose them a motor (motor manual sequencing skill, manual dexterity, balance, and aiming and catching) and a cognitive assessment. (visuo-spatial working memory, attention, inhibition and switching). By collecting our data, we propose a complete bivariate regression analysis, which follows the preliminary already published data. We focus on cognitive and motor individual abilities, to verify the correlation between them. Through this investigation, we would like to support the involvement of cognitive aspects in each part of the motor development of the children, even if depending on teachers, coaches and educators.

Introduction

In the present literature, the correlation between physical, motor and cognitive aspects in the development of children is widely considered [1-3]. Many studies take into account children's developmental impairments, like the Developmental Coordination Disorders (DCD) [4,5]. For instance, in the Canadian PHAST project [6], the author investigates about the impact of motor problems on physical activity of children, and its related physical consequences on health.

Moreover, evidence demonstrates that the motor coordination of children is linked to the acquisition and to the automation of a new motor or cognitive skills [7-9]. Furthermore, children with highly developed motor skills, seem to fulfil easily each kind of motor-and-spatial-linked cognitive task [10,11]. In fact, in some cases, the motor deficits can arise from a developmental deficit in the executive functions [12]. These functions incorporate all the necessary complex cognitive processes, in order to perform new or difficult goal-directed tasks, like [13] the ability to inhibit or delay a particular response, the ability to develop a plan of action sequences, the ability to hold a mental representation of the task through working memory [6,14]. In other words, the attention shift, inhibition, planning, working memory, and emotional regulation unavoidably take part in performing new or difficult goal-directed tasks. For instance, several children with DCD demonstrate scores below the average in cognitive tasks [15], which involve visuo-spatial skills, particular in the domain of working memory; other DCD children demonstrate poor inhibitory skills, and poor performance in planning and monitoring tasks [2-4]. A recent review [16] considers the best methods for improving executive functions, and it considers physical activity, like for instance basketball.

In the Italian context there are few investigations of this topic, for both DCD and Typically Developing (TD) children. Only preliminary normative data exist, which differ from other European country children outcomes. In the present study, we are continuing the previous research [17], enriching the findings. Our purpose is assessing a TD sporty sample, in order to identify the motor and the cognitive skills of these children. We have chosen this particular sample, because of its peculiarities. Before suggesting implications for the children with motor disorders, we consider as necessary to understand the TD children behavior; moreover, we have assessed a sporty sample –which plays basketball at a competitive level, as example of motor trained children. Furthermore, I take into account the vocational training of the basketball coaches, in order to identify their purposes by coaching these children. Because of the tactic and the strategic skills of basketball, as active game, I have chosen this sport to study the relations between cognitive function and motor performance [18,19] (Budde et al. 2008, Pesce et al. 2009). Focusing on motor control, Coker [20] provided an example of this integration in basketball practice. In fact, motion and cognition can collaborate as an integrated system to provide the motor control of the gestures. Motor control focuses on the neural, physical and behavioural aspects that are necessary to produce the correct movements [21]. In basketball practice, these systems are required to refine and relearn motor-skills, such as intercepting a ball at the correct time or improving the landing biomechanics to prevent injuries. Prerequisite abilities, such as control precision, multi-limb

*Correspondence to: Francesca Policastro, Department of Life Science, University of Trieste, Italy, E-mail: FRANCESCA.POLICASTRO@phd.units.it

Key words: motor and cognitive aspects, basketball players

Received: March 18, 2019; **Accepted:** March 25, 2019; **Published:** April 04, 2019

coordination, rate control, aiming and catching, timing control and dynamic flexibilities, are necessary for learning basketball. In this sense, cognitive and motor systems can be integrated to guarantee the best possible motor performance.

Taking into account the importance of a keen consideration of the cognitive aspects during basketball learning and practice, we continued our previous preliminary study [17], analysing both cognitive and motor skills.

Materials and methods

Procedure

The project was sent to and accepted by the Ethic Committee of the University of Trieste. Four basketball clubs in the region of Trieste (Italy) were invited to participate in this project. 82 parents gave their written informed consent to let their children participate in this study. These parents also filled an anamnestic questionnaire about the health status and the development of the child. The participants were assessed during training in an ecological situation, but in a quiet and reserved part of the gym. Testing was conducted in two 30–45 min sessions for each child. For each subject, the sessions were both completed in two months, which were always conducted by the same operator. This study started on January 2016 and ended on June 2017. Testing was randomised in order to eliminate order-related biases. The participants showed interest in the project and were motivated.

Participants

A total of 82 (59 boys and 23 girls) children have been recruited. They are between 7.23 and 10.99 years old (mean=9.36, SD=0.98, median=9.44). The inclusion criteria were: being aged 7–10.99 years old and playing basketball for at least the last two years. These children are playing basketball in mean since 2.8 years (SD=0.85). Furthermore, the participants are practicing basketball two or three times per week, at a competitive level. The basketball activity is not linked to the school program and there are no academic penalties if the children do not participate.

Measures

To assess motor and cognitive skills, the following neuropsychological tests had been used. Each test provides specific instructions to be administered in the correct manner, which allow us to create trials with different controls. In order to provide a complete assessment of cognitive and motor skills, the proposed tasks are at different difficulty levels, which are useful in characterizing healthy and sporty children.

- Movement Assessment Battery for Children—2 (MABC-2) [22]. The MABC-2 is a standardized test that is used to assess the motor skills of children with movement difficulties in the following domains: Manual dexterity (MD), aiming and catching (AC) and balance (Bal). Cluster and total standard scores for Italian children are provided [23], with higher scores demonstrating better performance. A total test score at or below the 5th percentile indicates significant movement difficulty, while a score between the 5th and 15th percentile indicates that a child is “at risk”. In these tests, the items and the scores were compared to the normative data of the uploaded version of the Italian MABC-2.
- Attention, Inhibition and Switching Assessment from the Neuropsychological Assessment—2 (NEPSY-II) [24]. This test is included in the “Attention and Executive Functioning” domain. It

requires each participant to look at a series of black and white shapes or arrows and name the shape, the direction or an alternate response depending on the colour of the shape or arrow. The subtests of denomination, inhibition and switching provide information about the accuracy of the sample in terms of timing and errors made when completing the tests. A comparison between the plots that show the relationship between time and errors is not possible as many scores were 0. In these tests, the items and the scores were compared to the normative data of the uploaded version of the Italian NEPSY-II.

- Manual Motor Sequences Assessment (MMSA) from NEPSY-II [23]. This test is included in the “Sensorimotor” domain. “Manual Motor Sequences” requires each participant to imitate and repeat a series of hand movements performed by the examiner. This counts the number of the manual sequences that participants can replicate. In this test, the items and the scores were compared to the normative data of the uploaded version of the Italian NEPSY-II.
- Corsi’s Test—Sequential Spatial Task [25]. This test assesses visuo-spatial short-term working memory. Each participant should imitate the examiner who taps a sequence of up to nine identical spatially separated blocks. Each participant should also be able to repeat this tapping sequence backwards. In this study I provide the forward (Corsi FW) and the backward test (Corsi BW).

Statistical analysis

I provide the statistical analysis using Matrix Laboratory[®]. First, the sample had been compared to the normative data given by the tests in a qualitative and in a quantitative way, whenever possible.

For the MABC-2 and its subtests, I provide the standard scores, and not the percentiles. Thus, there were no comparisons made using p-values, but qualitative considerations were undertaken, which were related to the incidence of motor deficits. For the three attention tasks, qualitative suggestions are provided due to the structure of the given standardized data, which consider the accuracy in terms of time and error relations. For MMSA and for the Corsi’s Test, it was possible to obtain a quantitative comparison. Second, the scores obtained by the participants have been used to provide a bivariate regression analysis, in order to understand the correlations between motor tasks (dependent variables) and cognitive ones (independent variables).

All the chosen tests are internationally validated and used. They are age standardized; in fact, the regression analysis doesn’t involve the age, as variable. Furthermore, they have also been adapted and standardized for the Italian population. The differences found between the countries highlight the importance in considering the cultural variables. For this reason, the standard population given by the tests allowed comparison with the subjects of the study.

Comparing the sample to a standard expected normative Italian population could partially reduce the limitations of not having a control group. This study aims to collect data about Italian TD sporty children, in order to obtain preliminary data about their motor and cognitive development, and the existing correlations.

Results

Data analysis and description

The following (Figures 1, 2 and 3) show the distributions of the sample, considering the motor and the cognitive assessment.

Table 1 shows the means, the standard deviations, the ranges and the expected values for the considered variables.

The following statistical analysis provides a qualitative and – whenever possible quantitative analysis.

For the study of the qualitative parameters, I used the comparison between expected and observed data through tables' comparisons. The quantity of zeros in the Table for NEPSY-II Attention tests suggested to only deducing the percentage, in which the present sample ranks higher than the expected. When possible (for MMSA, Corsi FW and Corsi BW), I provide the quantitative analysis through the t-test.

The sample ranks in a large range of scores, for all the items of MABC-2. The Aiming & Catching skill presents the highest standard score (12.6), whether the Manual Dexterity the lowest (10.5). The Aiming & Catching score influences the total outcome of MABC-2 (12.2).

In NEPSY-II attention sub-tests (where only the qualitative analysis was possible), it is important to highlight that the majority

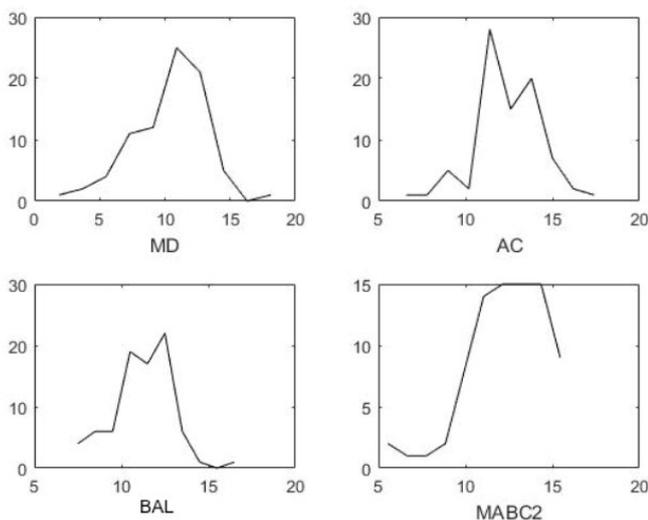


Figure 1. Sample distribution for the motor test (Manual Dexterity, Aiming & Catching, Balance, total score of MABC-2). x-axis=number of subjects; y-axis=score

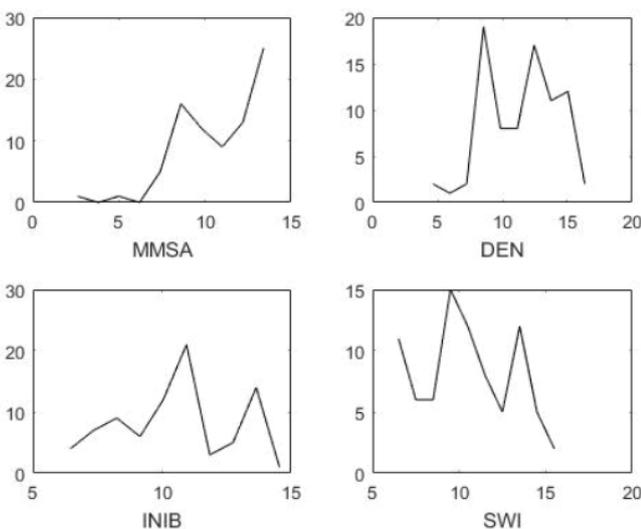


Figure 2. Sample distribution for the NEPSY-II subtest (Motor Manual Sequences Assessment, Denomination, Inhibition, Switching). x-axis=number of subjects; y-axis=score

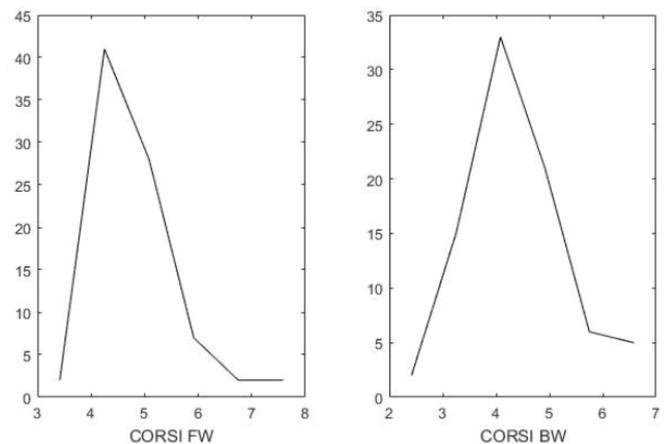


Figure 3. Sample distribution for the Corsi's Test (Forward and Backward). x-axis=number of subjects; y-axis=score

Table 1. Means, SDs and ranges of score for the study variables. MABC-2=total score of Movement Assessment Battery for Children-2; MD=manual dexterity; AC=aiming and catching; Bal=Balance; MMSA=motor manual sequences assessment. All the scores are age-standardised

Test	Mean	Median	SD	Range
MABC-2	12.2	12	2.1	5–16
MD	10.5	11	2.7	1-19
AC	12.6	13	1.9	6-18
Bal	11.7	12	1.7	7-17
Denomination	11.4	12	2.8	4–17
Inhibition	10.5	11	2.4	6–15
Switching	10.9	11	2.7	6–16
MMSA	10.9	11	2.3	2–14
Corsi Front	4.7	4	0.9	3-8
Corsi Back	4.4	4	1.1	2–7

of the observed sample ranks higher in each subtest, compared to the standard population (59% in denomination, 60% in inhibition and 64% in switching).

In NEPSY-II MMSA test, through the t-test, the sample demonstrates statistically significant higher scores compared to the standard population provided by the test, with a p-value<0.01 (standard population: mean-score=10, SD=3).

In Corsi FW, the mean-score of the sample is 4.7 (SD=0.9), with a normal range of 3–8 points. In Corsi BW, the mean-score of the sample is 4.4 (SD=1.1), with a normal range of 2–7 points. The standardized score depends on the age of the child, and it changes for every year. A brief stratification of ages and the t-test scores (Tables 2 and 3) demonstrate, that significant differences between the sample and the normal population exist (significance at p<0.05).

In Corsi FW, there are no differences between the sample and the normative data for 10-years-old children (p-value=0.18). The 9-years-old children of the present sample rank lower than the normative population, with a significant difference (p-value<0.01). 7-and-8-years-old children rank higher than the normative population, with significant differences (7-years-old-p-value=0.04; 8-years-oldp-value<0.01).

In Corsi Back, there are no differences between the sample and the normative data for the 7-years-old children (p-value=0.20). In the other age-bands, the children score higher than the normative population, except the 10 years-old children (p-values<0.01).

Table 2. Stratification for ages of Corsi FW. *significant p-values, at p<0.05

Age	Mean	SD	Expected Mean	t-Value	p-Value	n
10 years	4.58	0.83	5.03	0.92	0.18	24
9 years	4.52	0.71	4.94	-4.75	<0.01*	25
8 years	4.81	1.11	4.66	-4.84	<0.01*	27
7 years	4.83	1.47	4.34	-1.98	0.04*	6

Table 3. Stratification for ages of Corsi Back. *significant p-values, at p<0.05

Age	Mean	SD	Expected Mean	t-Value	p-Value	n
10 years	4.25	0.99	4.37	-4.54	<0.01*	24
9 years	4.52	1.23	4.35	-4.48	<0.01*	25
8 years	4.30	1.17	4.22	-4.39	<0.01*	27
7 years	4.33	1.21	4.03	-0.89	0.20	6

By considering the children’s behaviours during the assessment, the uninterested attitude of the older children -who underestimated the difficulty of the test could be an explanation for these results.

Bivariate regression analysis

All the pairs of variables, which show a determination coefficient (R²) of at least 0.05. This kind of coefficient supports the existence of at least a weak correlation between the variables. Taking into account the existing literature, I considered the motor tasks as dependent variables (MABC-2 items and MMSA), and the cognitive tasks (attention and working memory tasks), as independent ones.

At the end of this document, I provide the Attachment 1, with the complete bivariate regression analysis.

Discussion

The first aim of this study was to analyze the motor and the cognitive abilities in a TD, sporty sample of Italian young basketball players.

The statistical analysis seems suggesting the hypothesis, that the basketball practice could influence the motor skills of the children. In fact, Aiming and Catching skill is the most developed in this sample (score=12.6), compared to the Balance (score=11.7) and the Manual Dexterity (score=10.5). In fact, very early the young basketball players exercise their abilities with the ball. By considering the cognitive outcomes, there are some differences between the items. In the attention sub-tests (where only the qualitative analysis was possible), more than half sample demonstrates to score higher than the normative sample (denomination 59%, inhibition 62%, switching 62%). These data suggest, that basketball playing might produce an indirect effect to some aspects of the executive functions. In the MMSA, the sample score significantly higher than the normative data (t-test, p-value<0.01); it seems an easy task for these subjects. The ability to imitate motor manual sequencing might not require a large readiness to act, as well as the online control of the action. Moreover, this test requires the children to imitate an action, and not to produce a completely new one. By considering the more difficult tasks, that these children normally perform, their scores statistically differ from the standard population.

The Corsi’s Test demonstrates that the results differentiate for age. In fact, in the Forward subtest, for the older children (10 years old) there are no statistical differences between the normative and the sample outcome (p-value=0.18). At the Backward subtest, the same children

score lower than the expected outcome (p-value<0.01). In the other age-bands, both in the Forward and in the Backward subtest, the sample scores higher (p-values<0.01), or at the same level (p-value=0.20) of the normative data, with no significant differences. During the assessment, I noticed that the 10-years-old children seemed uninterested in this activity and overestimated the task: this behavior could have influenced their performance. These data support the importance of the self-awareness of 10- years old children [26]. Like the teachers do, also the coaches and the educators could support the self-assessment and the self-consciousness, by considering the processes involved in those tasks. For this age-band, the enrolment of metacognition process seems necessary, in order to reach the expected aims.

This first part of the statistical analysis permits to understand that the cognitive skills of this TD sporty sample are in general well developed. Generally, some differences between the considered sample and the normative population (given by the tests) exist. These partial preliminary data are not so consistent to affirm, that the basketball practice influences the cognitive development; anyway, I want to highlight one more time, that many children of this sample demonstrate high developing cognitive skills.

The second aim of this study was to identify the correlations between executive functions and motor abilities in this specific sample. These data are preliminary, in order to orientate my future study about these topics; for this reason, I discuss these correlations, even if they were weak or moderate. According to the previous evidence, five positive correlations emerge. In literature, attention is strictly related to the motor development [11,17]. In this sample, the total score of the MABC-2 correlates to the Denomination subtest of attention (R²=0.055). The research of Roebbers and colleagues [7] demonstrates the involvement of attention on the development of the motor skills. The Manual Dexterity task shows the same correlation of MABC-2 to the denomination subtest (R²=0.062). These motor tasks include a measure of speed and accuracy in each hand separately, a timed bi-manual task, an untimed drawing task and the reception and shooting tasks [27,28], which all require important attention prerequisites.

The MMSA correlates to the inhibition task (R²=0.142); this outcome supports the impact of attention on the motor plan to choose. By considering the request of this task to copy a bimanual configuration, the MMSA strongly involves the sensorimotor competences. In fact, the imitation ability needs a mature sensorimotor integration, also managed by the inhibition function. In particular, for a basketball sample, the correlation between MMSA and Inhibition is important, because of the needing of hands inhibitory control during the imitation, in all the learning phases.

The previous evidence supports the emerged correlations. This specific sample reveals as correlations, which are strictly involved in the motor building. The physiological explications of these correlations come from the shared neural mechanisms, between frontal cortical areas and cerebellum processes [12,27,28]. Considering the Corsi’s test results, the working memory doesn’t show correlations to the MABC-2 skills. According to the previous literature [1], the importance of the working memory in the motor action is undoubted. Nevertheless, for this specific sample, the correlations don’t emerge. An explanation of this outcome could be due to the uninterested attitudes of the older children in the WM evaluation.

Conclusion

The beginning goal of this study was to assess a TD sporty sample, in order to identify motor and cognitive skills, but also the interaction between these abilities. I have chosen this sample, because of the peculiarities of the sport they are practicing. In a social context, where the children are at risk of sedentariness, a sporty sample represents a group of active and trained children: for my purposes, both the physical and the cognitive training are important.

By considering this sample, I have tried to analyze as deeper as possible the level of motor competence and some executive functions skill. In literature there is evidence about the correlation between cognitive and motor development, but it is focused on not-TD children. I have decided to develop this study, in order to enrich the literature about TD and sporty children, but also to understand how to be useful to help their development. In fact, the correlations implicate, for instance, that the coaches could consider also cognitive aspects in training. For instance, the basketball players frequently utilize their denomination skills when they focus on the number and the position of the player that they are defending. Attention is a necessary executive function for developing correct movement strategies and inhibiting unwanted movement. The players utilize their ability to imitate motor manual sequences every time they are learning a manual task by imitating the coach, such as during the ball-handling practice. Basketball practice is also based on visuo-spatial structures, which are used to create and improve complex motor tasks, thus creating “automatic” movements to play. For instance, players use their visuo-spatial working-memory when they learn how to dribble around opponents and when they recall this and other complex automated motor plans during the game. The previous examples would like to highlight how motor and cognitive systems are integrated to guarantee complex controlled motor performance, also in a specific sample of TD sporty children.

The emerged correlations, which especially highlight the connection between attention and motor tasks –in particular Manual Dexterity tasks-, support the importance of integrating this aspect, during the motor and sport activity. In order to help these sporty children to improve their skills, this could be a new learning starting point.

These are preliminary data, which highlight the impact of the cognitive aspects in the motor development. Through these results, I suppose that a cognitivecentred training could positively impact on these sporty children. The introduction of cognitive-aware tasks during training could facilitate motor learning itself. Through this work, I'm continuing my research about the integration of different disciplines and constraints, in order to understand the development of the children, both TD and not-TD.

In the future, it could be useful to increase the sample size to confirm the present correlations and to verify whether there is a corresponding increase in their magnitude. It could also be interesting to create and validate a practical training proposal, which would involve training of the executive functions, especially attention. Anyway, another suggestion naturally arrives: could an integrated motor cognitive approach during the activity (or the sport practice) help the motor development of children, who show motor difficulties?

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